

Design Challenges of Locomotive Diesel Engines

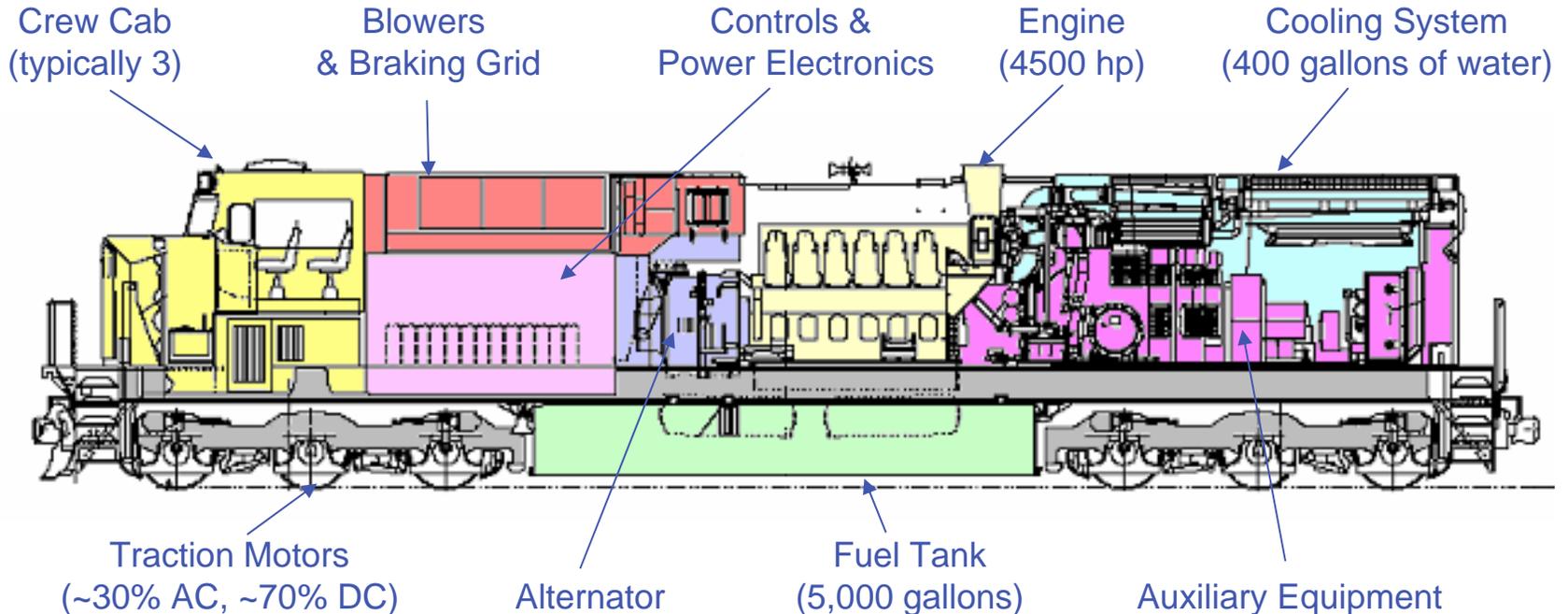
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GE Global Research Center

11th Diesel Engine Emissions
Reduction Conference

Chicago, Illinois
August 24, 2005



Typical Locomotive Configuration



- The longest locomotives are 74-76 feet (track radius restrictions)
- Average height is 15 feet and 5-1/4 inches (infrastructure restrictions)
- Fully-serviced locomotives weigh up to 420,000 pounds (35 ton/axel)
- The life expectancy for locomotives is approximately 20 years

Locomotive Operation

- Locomotive Consist

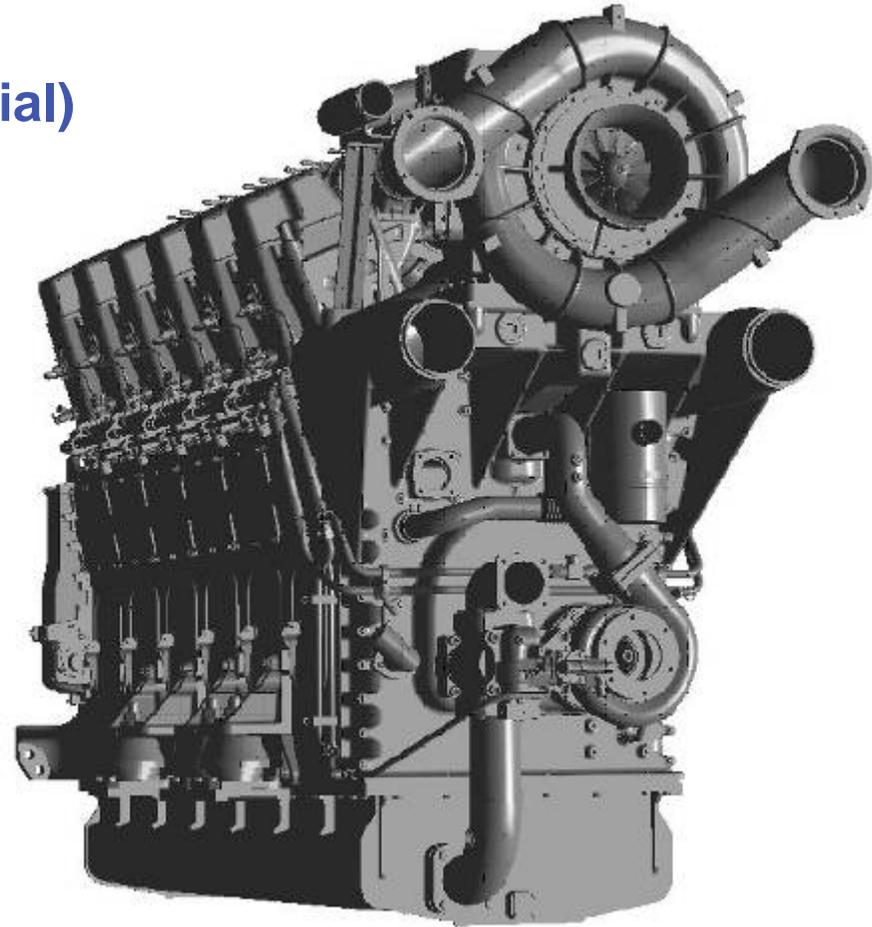


- Two or more locomotives in same train
 - Can face either forward or backward
 - Can be located anywhere in the train
- Tunnel operation
 - Trailing locomotive(s) see exhaust from lead loco(s)
 - Effective ambient > 180 F (emissions, durability)
 - Shock & Bending loads
 - 3g's longitudinal with more than 400,000 lbs
 - Mechanical loading on pipes & attachments

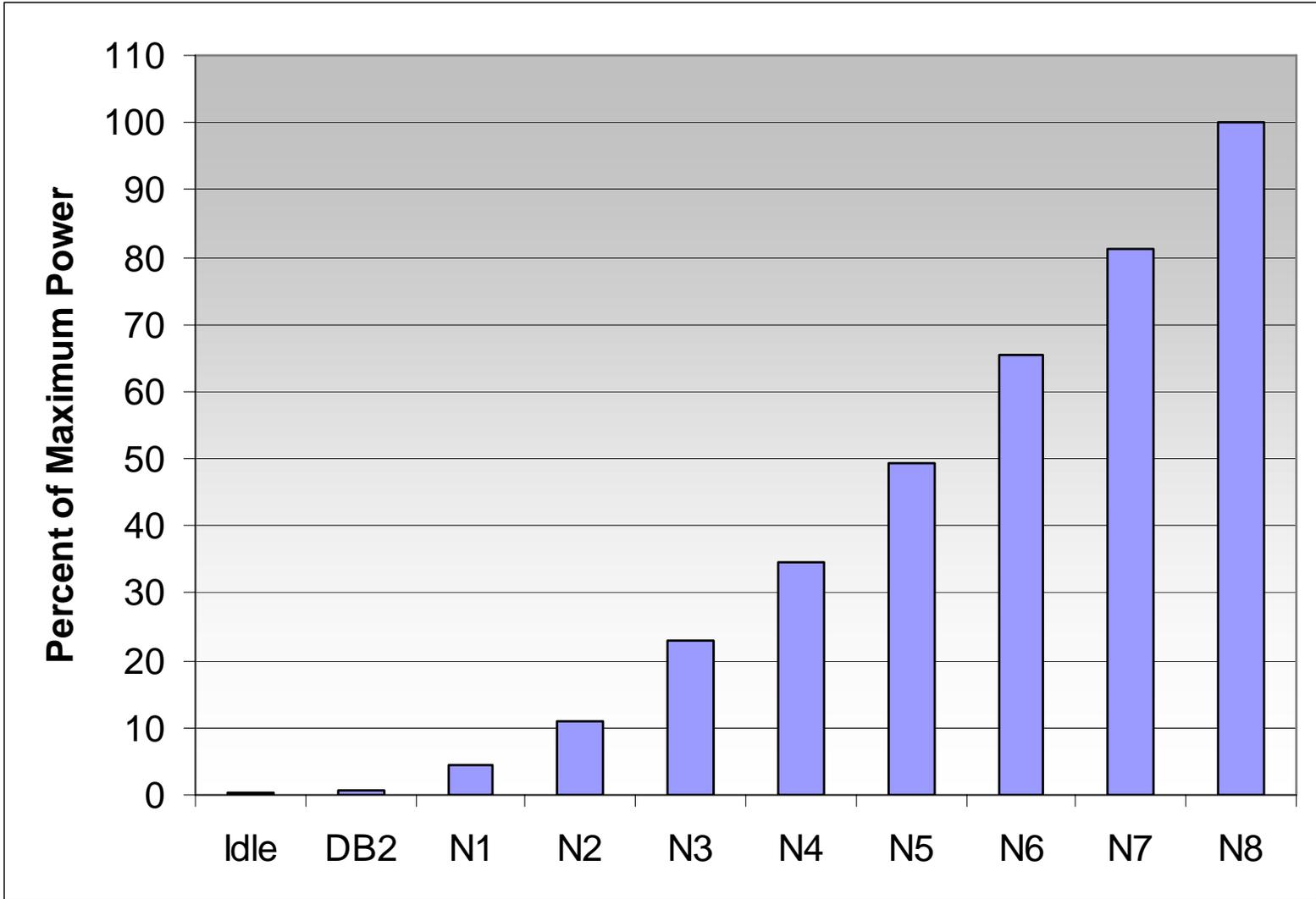
GE Evolution Locomotive Diesel Engine

Four-stroke
Direct-injected (unit pump system)
Single-stage turbocharged (axial-radial)
Hybrid air-to-air charge air cooling

Bore	mm	250
Stroke	mm	320
Displacement	l/cyl	15.7
# Cylinders	-	12
Total Displacement	l	188
Power	hp	4500
Power/cyl	hp/cyl	375
BMEP	bar	20.3
Speed	rev/min	1050
Mean Piston Speed	m/s	11.2



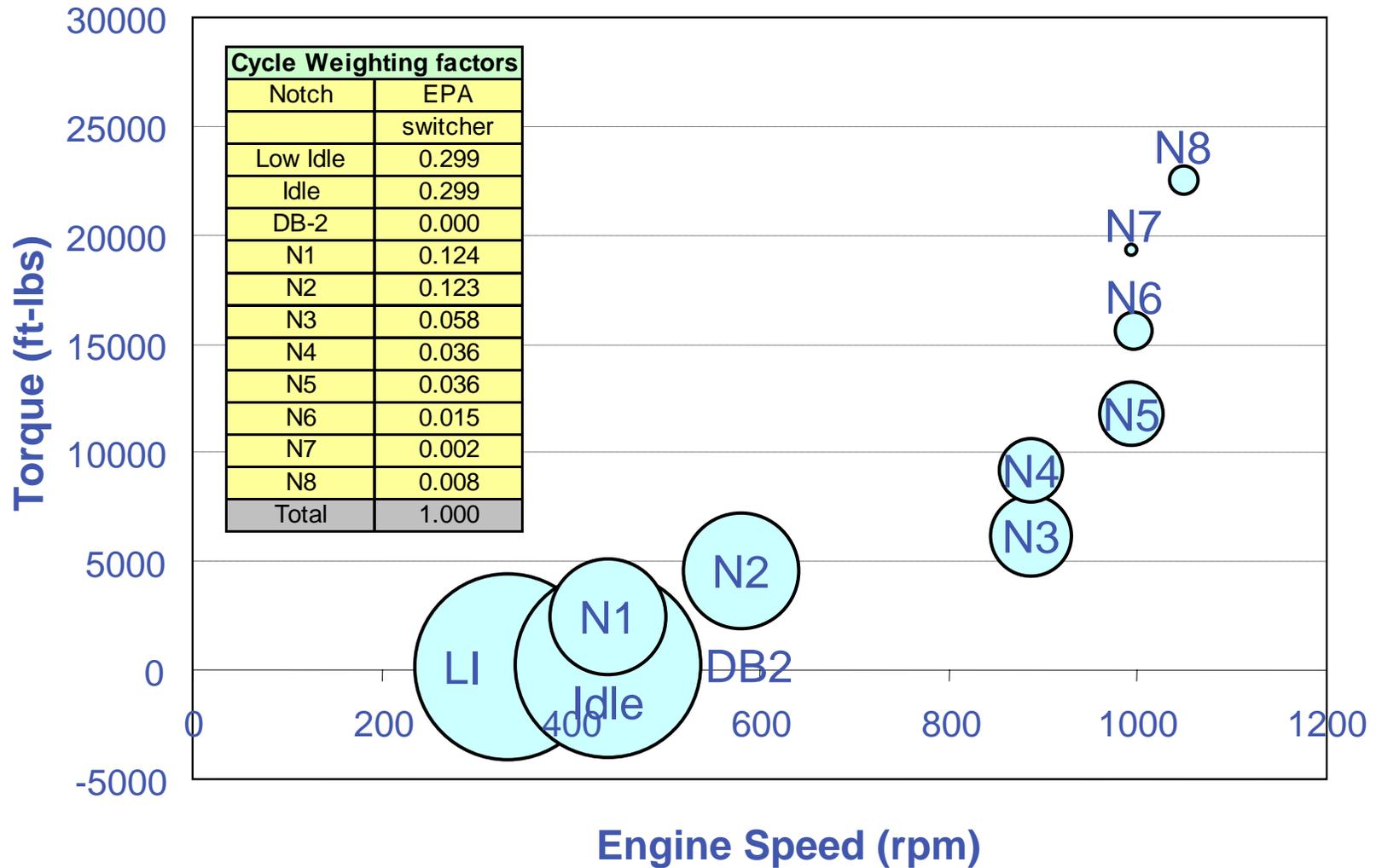
Locomotive Operation Points - Notches



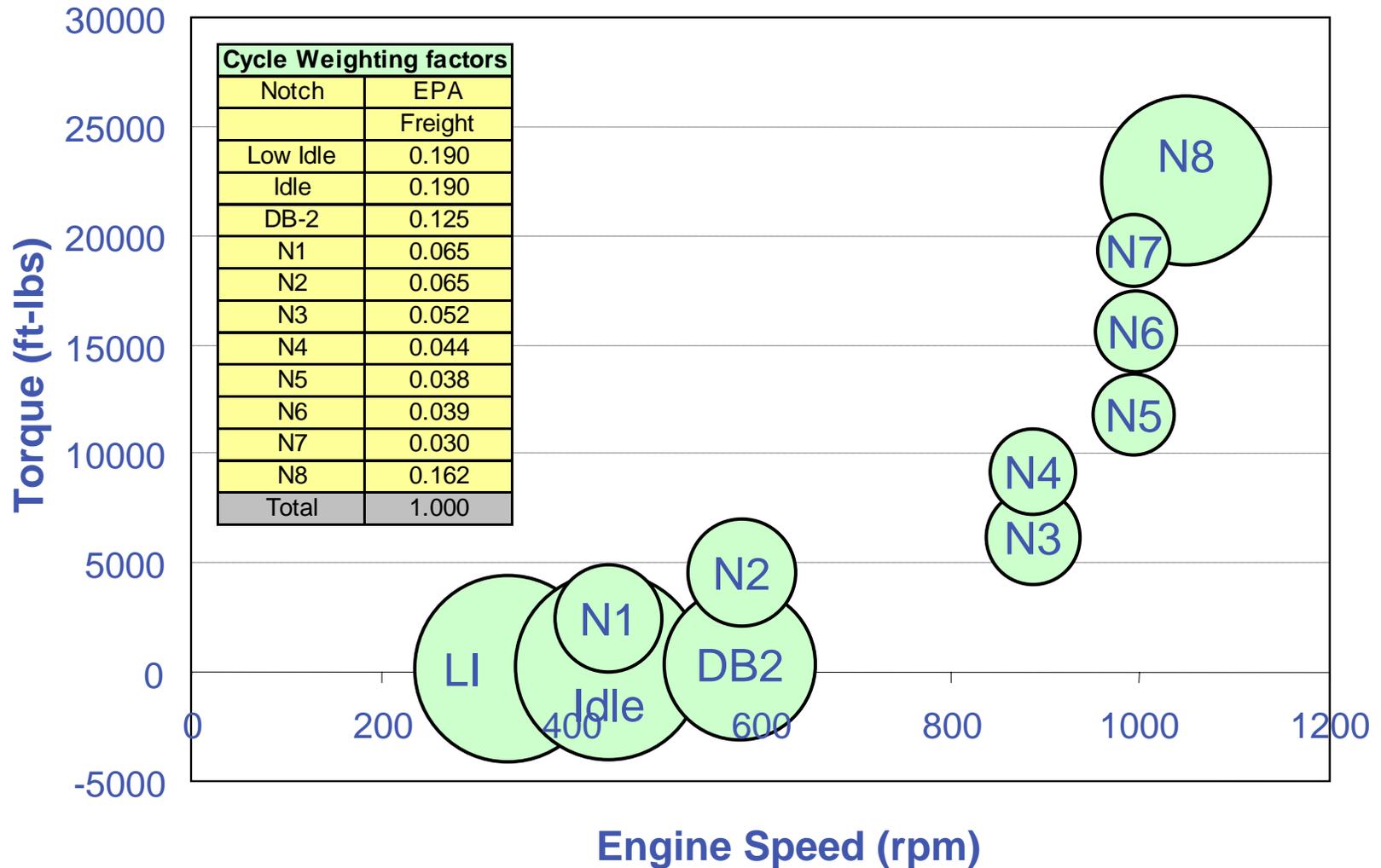
Emissions Certification

- Ambient condition range
 - > Ambient temperature from 45 F to 105F
 - > Sea level to 7000 ft
- Useful life
 - > 7.5 x (rated HP) [MW-hrs]
33,750 MW-hrs for a 4500hp engine
 - > 10 years
- In-use testing

EPA Locomotive Switcher Weighting



EPA Locomotive Freight Weighting

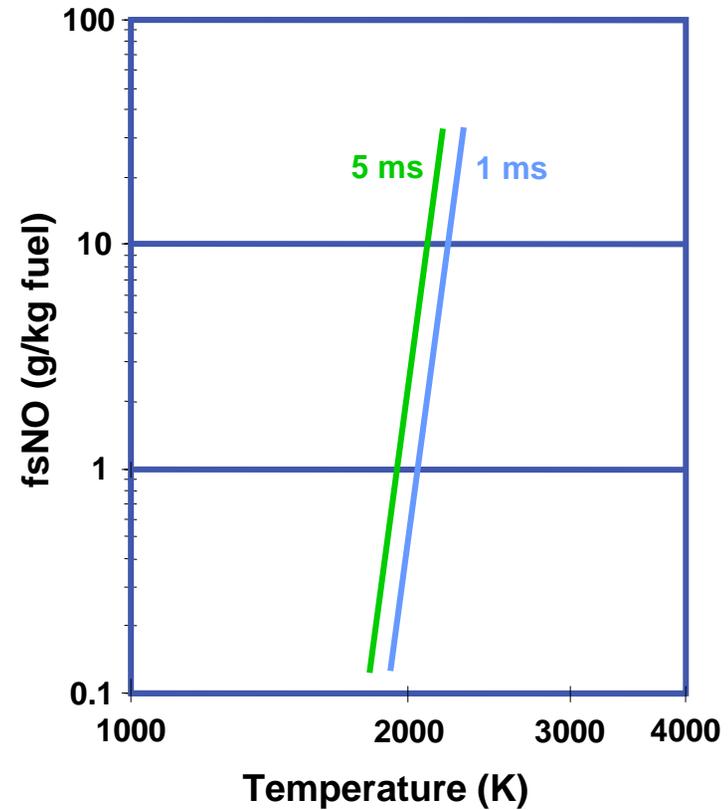
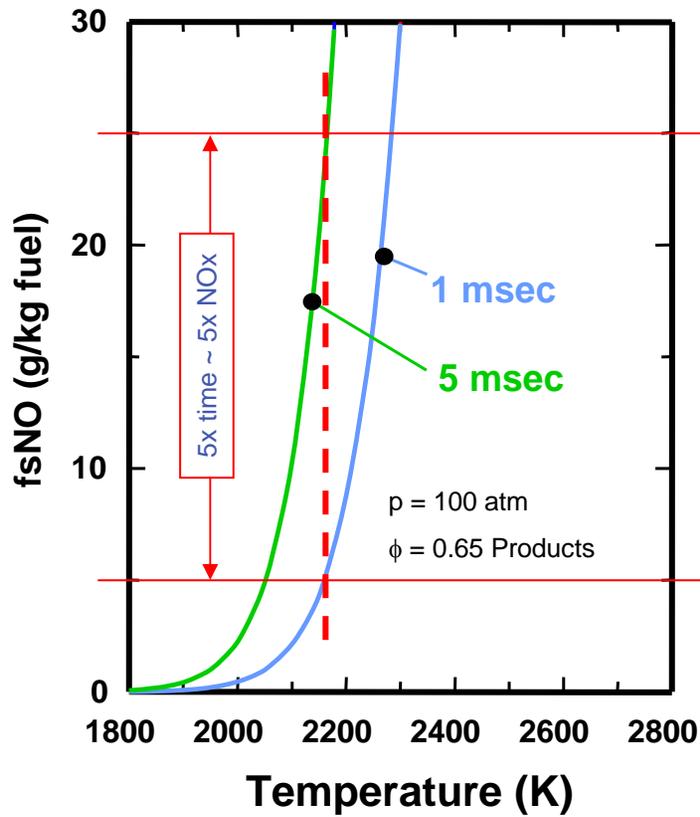


EPA Locomotive Standards

Tier	Cycle	Gaseous and Particulate Emissions (g/hp-hr)			
		NOx	PM	HC	CO
Tier 0 (1973-2001)	Switcher	14.0	0.72	2.10	8.0
	Line-haul	9.5	0.60	1.00	5.0
Tier 1 (2002-2004)	Switcher	11.0	0.54	1.20	2.5
	Line-haul	7.4	0.45	0.55	2.2
Tier 2 (2005-?)	Switcher	8.1	0.24	0.60	2.4
	Line-haul	5.5	0.20	0.30	1.5

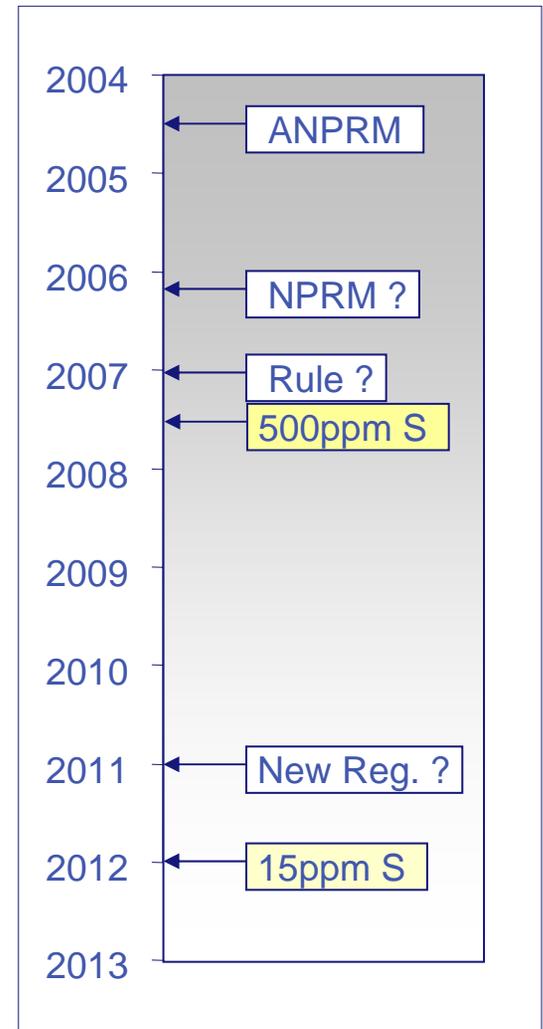
NO_x Emissions

NO_x formation function of Temperature and Time



EPA Locomotive Rule Making Timeline

- ANPRM published June 29, 2004
- Comment period closed August 30, 2004
- NPRM expected ~ Q1-2006
- Final rule expected ~ 2007
- 500 ppm sulfur fuel June 2007
- Compliance time frame
 - > Not clear if 1 or 2 steps
 - > Expect new reg. ~ 2011
- 15 ppm sulfur fuel 2012



Summary

- Consist operation and tunnel environment are major design concerns
- The lower speed of the locomotive engine provides longer residence time for NO_x formation
- Soot not as speed sensitive as NO_x (combination of formation and oxidation)
- Expect EPA to publish NPRM for Tier 3/4 locomotive emissions standards in early 2006